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TO MODEL 260 LASER TV CINETHEODOLITE

by

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Applying TV Centroid Tracking Technology to Model 260 Laser TV Cinetheodolite

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Abstract: New photoelectronic equipment developed recently for range measurement 260 laser TV cinetheodolite is described. The equipment measures the trajectory of flight vehicles and can track targets in three ways: semiautomatic tracking, remote automatic tracking and computationally, with high accuracy and good ability for real-time measurements and real-time output. The laser ranging system mounted on the equipment is capable of single-station orientation.

The digital real-time TV centroid tracker consists of a video processor, a projection processor and a tracking-window controller, using parallel processing based on TMS 320 series high-speed numerical signal processing chips and pipelining, combined with analog image preprocessing. The equipment passed indoor tests, airport tests, and field tests. For sea skimming missiles without cooperative target, single-station tracking measurements were made with a very high return echo ratio, at distances to 10.4 km.

1. Preface

During the past 30 years, TV tracking gradually developed into a new cutting-edge technology, widely applied in fields such as product checking on industrial production lines, various automatic fire control systems in military operations, external trajectory measurement instruments, as well as different kinds of

TV guidance heads. Interestingly, the photoelectric tracker centralized with TV tracking can markedly expedite the incorporation of artificial intelligence in weaponry as well as military facilities. Similarly, with a totally passive operation pattern, this technique, based on brightness contrast between target and background, spectrum and image, can be used to capture relevant data from the target tracked so as to disable active enemy interference, and ultimately overcame the vulnerability that radar has shown to electronic jamming.

The newly developed model 260 laser TV cinetheodolite is a successful example of applying TV tracking in real-time tracking measurement equipment. Technically, this tracker, coupled with a digitalized device, is equipped with a microcomputer based on two FMS 220 series high-speed digital signal processors, for performing concurrent processing. Further, by using operational software dedicated to statistical classification and projection, this instrument enjoys several advantages, such as intelligent image processing, high precision measurement, high anti-jamming performance, and so on.

Typically, TV trackers currently used can be classified as three forms, edge tracking, centroid tracking, and correlation tracking. Specifically, the edge tracking method is used to track the upper left edge of a target, which can be achieved as analog processing over the video frequency signal without excessive digital arithmetic operations. Thus with its specialty of simple structure and fast reaction, it is considered to be the earliest and, most importantly, the more efficient method in dealing with very contrastive targets. Yet this method also has some disadvantages, such as poor anti-jamming capability and high random error rate, since the tracking point is prone to change with the variation of the target altitude and illumination conditions.

The centroid tracking method takes the target shape center (it approaches the center of gravity of the target only on the assumption of equal density) as its tracking point. To locate the tracking point, data on target shape must be collected and related arithmetical operations must be performed. Hence, with this scenario, centroid tracking is believed to be more complex than edge tracking, structurally speaking. Even so, however, centroid tracking still possesses its own superiority, including the feature of being less affected, even by change of the target shape and illumination conditions, as well as high precision tracking and stability.

Correlation tracking, based on special target shapes, can be used to track targets under any intricate background and conditions or any designated point on a target. As a result, it claims precedence over the above two methods with its capability of identifying targets against complicated backgrounds. Theoretically, to realize real-time processing, the size of reference window is required to be smaller because of present hardware standards and the large volume of arithmetic operations. Otherwise, the special point is apt to suffer from various interferences, making it hard to ensure tracking stability.

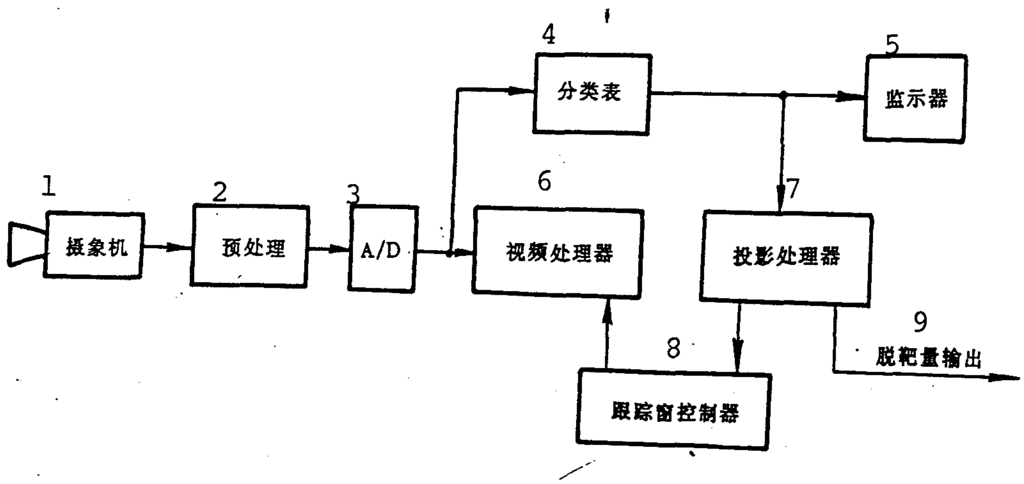
The centroid tracker we constructed can deal with medium and small targets against a less complex background. Targets shown on the screen can be either large enough to cover three quarters of the field of view or else small enough to occupy just one line on the screen. This condition, however, can become relatively stable when the need of an adequate signal-noise ratio is satisfied, which enables the centroid tracker to perform its task very smoothly.

2. TV Centroid Tracker

The major technical indicators of the TV centroid tracker are as follows:

Field frequency	40 Hz
Resolution	256x256x6 bits
Field of View	34′ (f=1m) 17′ (f=2m)
Track errors	Maximum value of system error 3′ Mean square value of random error 30′ (in the case of maximum speeds 20°/s, and maximum acceleration $7°/s^2$)

Its structural block diagram is shown in Fig. 1.



Key: 1. Video camera; 2. Preprocessing; 3. A/D; 4. Classification chart; 5. Monitor; 6. Video frequency processor; 7. Projection processor; 8. Tracking window controller; 9. Target miss rate output

The TV centroid tracker consists of image preprocessing and its conversion, a video frequency processor, a projection processor, tracking-window controller, etc.

Upon being preprocessed, the video frequency signal transmitted from the video camera is sent to the AD converter to be transformed into a 256x256x6bit video frequency digital

signal. By processing the digitized signal, the video frequency processor can then discriminate the target from the background and designate them by an X-Y diagram. Target image elements in the X-Y diagram are shown as 1s, and the background points as 0s.

The principle of discriminating targets by the video frequency processor is based on statistical principles and the Bayes classification method. First the tracking window is divided into two regions, the one covering the target is called the target region (hereinafter referred to as TR); and the other surround the target is called the background region (hereinafter referred to as BR), as described in Fig. 2. The rule set for dividing the regions requires that BR be as close to the target as possible, but the target is not allowed to enter the region. That is to say, there is not target-related gray scale feature except the background related gray scale in BR. While in TR, there are various target-related gray scales. Thus, image elements involving a target in the TR can be discriminated as long as gray scale features in BR are derived through real-time processing and compared.

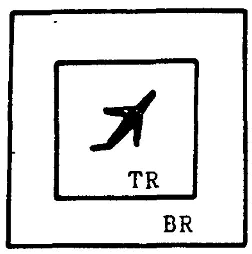


Fig. 2.

Acquisition of gray scales in BR an TR can be achieved with a real-time histogram memory. By using a computer, the histogram can be analyzed so that a classification chart can eventually be generated. The video frequency digital signal, i.e. grey scale per image element, outputted from an A/D converter, can be used as an address to inquire the classification chart stored in the

high-speed RAM and to create an X-Y diagram of the target region, following the classification in real-time processing. Based on field-by-field updated histogram data processed, this classification chart can be acquired on site and therefore is significantly real-time in character.

The X-Y diagram of the target region outputted from the video frequency processor is separately transmitted to the monitor for display and the the projection processor.

The projection processor, in accordance with the projection computing principle, can perform projection decomposition of the X-Y diagram in the X and Y directions. Further, it subdivides the projection area enclosed in different directions into eight divisions and takes the X and Y coordinates corresponding to four divisions of the centroid location. Based on this location, the centroid target miss rate and target size can be computed, and so the automatic tracking window size is modified through a real-time processing and then sent to the tracking controller in order to construct an automatic tracking window that can vary with the target size.

The centroid target miss rate can be separately transferred to the cinetheodolite servo system and the mainframe computer in analog and digital forms to execute automatic tracking over moving targets, real-time output, and recording of the target miss rate.

Another function that the projection processor can perform is that it can, along with its relevant subsystems, enable the cinetheodolite to undergo a smooth conversion among the several tracking modes.

It is determined that both the video frequency processor and the projection processor function with the TMS 3320 series high-

speed signal processor as their central unit, together with various auxiliary chips. They form a dual system, with the structure of parallel processing and production line, which can give the TV centroid tracker a time-processing capability.

3. Conversion of State

Frequently, some photoelectric tracking devices are equipped with multiple tracking modes, which can undoubtedly add more functions to these devices. Nevertheless, when dynamic conversion is required among different tracking modes during their operation, an undesired overshoot may sometimes occur during a sudden switching, caused by a series of factors, including temporary processing pattern of the system, switching time lagging, and the variation of target miss rate at the instant of switching, which can eventually lead to missing targets as they happen to pass from the field of view. Therefore, to have an excellent tracking performance, it is vitally important to maintain reliable switching ability among various tracking modes.

The model 260 cinetheodolite operates in three modes, semi-automatic tracking, TV automatic tracking and digital guidance. The random zero-point technique is adopted in order to effectively ensure smooth conversion among various modes during dynamic tracking.

The fundamental rule of this technique is that when the tracked target is guided into the field of view in the semi-automatic or other modes, which are then replaced by TV automatic tracking, the existing target miss rate, normally by small increments, instead of being immediately carried into the servo system stepwise, is gradually sent to the servo system from the TV tracker after the target, located at the random zero point at the instant of switching, stays on the spot for 23 seconds,

making the system move gradually and smoothly from random zero

point to real zero point. When arriving at a small range of real zero point and receiving a real target miss rate from the TV tracker, the system is eventually brought into a real tracking state. In this way, the ever-present overshoot state resulting from sudden switching can be substantially curbed and replaced by, in contrast, a smooth transitional and reliable conversion process.

The random zero point technique, following its application to the model 260 cinetheodolite and going through a large number of field experiments and range practice, proves that, with proper design and programming, balanced system performance and simple operation, it can greatly ease the operator's psychological pressure incurred from state conversion and consequently increase the reliability of the whole system.

4. Results From Practical Use

With a TV centroid tracker, the model 260 cinetheodolite underwent a field test at the DA Fang Shen Airport in Changchun City, from September through November, 1989. To check the video frequency processing capability of the tracker, different illumination conditions and backgrounds of clear sky and patchy clouds, as well as the aircraft with various flight attitudes, were all tracked throughout the flight operation from its take-off, circling in the air until landing, and the results turned out to be successful. Moreover, the delicate design integrating the image preprocessing circuit with the arithmetic classification operation performed by the video frequency processor produced a rather strong target discrimination capability. Noticeably, during a trial experiment conducted on a training plane under a patchy cloud background, the target was

satisfactorily discriminated and locked on by a stable and reliable automatic tracking system. In fact, this success, in terms of the design principle of statistic classification, was truly beyond our expectations.

In may 1990, the model 260 cinetheodolite successfully passed a series of indoor tests, including an accuracy test under sine tracking with indicators reaching or exceeding technical requirements.

Between October and December, 1990, a field trial flight was undertaken at a naval test base, during which this tracker performed continuous night tracking over a celestial body for about 5 hours and made a comparison between the filming measurement accuracy and TV measurement accuracy. It also tracked and measured a target ship and aircraft and furthermore, completed single-station TV automatic tracking and measurement, with great success of a sea-skimming missile without a cooperative target against a strong illumination background from sparkling sea waves. During the test, the tracking and measurement range extended to as much as 25 km, and the laser with a high return echo ranged up to 10.4 km. During the missile flight of dozens of seconds, the overall system accomplished real-time, high-precision tracking and measurement, starting from semi-automatic interception and acquisition at the instant of missile launch to a rapid and smooth switching into TV automatic tracking.

Practice demonstrates that the TV centroid tracker has remarkable efficiency and practicality.

5. Conclusion and Discussion

Since a TV centroid tracker was successfully applied to the model 260 cinetheodolite, tracking and measuring as well as

automatization of the cinetheodolite were greatly enhanced.

Combined with digital image processing, this tracker, featuring not only simple structure, stable performance, strong anti-jamming capability, but also flexible programmability, can have various applications. For instance, the infrared and low-light imaging instruments, as a replacement for the currently used visible light video camera, can be simply used with only minor software modification, with its basic system structure remaining unchanged.

It is noted that the correlative tracking mode shows its own conceptual advantage if special point tracking is needed because of fairly complex background and a target large enough to fill the field of view. Hence, it is necessary and very efficient if the correlative tracking mode and centroid tracking mode complement each other.

The foregoing project is a result of long-term teamwork, starting in the early 1980s under the direction of Zhu Yunqing, a senior engineer. Among those who undertook the model 260 cinetheodolite research are Yao Lichang, Wangyi and Ge Wenqi. They played a major role in accomplishing this project. The participants involved in this project also included Hang Lianqing, Zhang Beling, Liu Liqin, Guo Tingzheng, Chang Jinchang, Ma Linan and Bai Yihong.

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